Tools to Study Tornados and Galaxies

Suggested Grade Level(s): 8-12
Estimated class time: 1 hour

Summary

Students will investigate the Doppler Effect and discover how the same principle can be used to identify a possible tornado in storms clouds and investigate the rotation of distant galaxies.

Objectives

- Students will show how the Doppler Effect causes electromagnetic waves to be shortened or lengthened as an object approaches or recedes from the observer.
- Students will construct a velocity radar "image" that indicates a Tornado Vortex Signature.
- Students will compare their meteorological radar data to astronomical visible light data collected from galaxies to see the same principal holds true using any wavelengths of the spectrum.

National Science Standards

- NS.5-8.1 SCIENCE AS INQUIRY
  As a result of activities in grades 5-8, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.1 SCIENCE AS INQUIRY
  As a result of activities in grades 9-12, all students should develop
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- NS.9-12.4 EARTH AND SPACE SCIENCE
  As a result of their activities in grades 9-12, all students should develop an understanding of
  - Origin and evolution of the universe

Knowledge Prerequisite

Students should be familiar with the Electromagnetic Spectrum and the concept of Doppler Shift. Visit these sites for excellent background:
http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html and
http://imagine.gsfc.nasa.gov/YBA/M31-velocity/Doppler-shift-2.html

Materials

For each group of 2 or 4 students:

- Safety glasses
- A Slinky toy (plastic is recommended, but either plastic or metal will work)
- Meter stick
- Velocity (Doppler) RADAR image of Raymond, Illinois for each student (included at the end of this lesson plan)
- Galaxy map of NGC 4254 for each student (included at the end of this lesson plan)
- Red, Green, Orange, Yellow, and Blue colored pencils

Procedure:

I. Engagement

Set up the following scenario for your students:

It is mid-May and you are sitting in science class trying to pay attention as your teacher explains research about motion in deep space. She says that experiments have revealed information using changes in visible light, but your mind wanders to thoughts of coming summer vacation. You notice that the sunny spring sky outside has changed to dark and ominous when suddenly the principal announces on the PA that a TVS has been sighted and all students should follow emergency weather procedures! You remember that TVS stands for Tornado Vortex Signature and feel a rush of adrenalin. The lesson on space ends abruptly as your class evacuates to the basement of your school where you crouch against the walls until the All Clear signal is given and you return reluctantly to class. When everyone is seated again, the teacher asks how studying tornados with RADAR could be related to studying light shift from galaxies? The tornado was a near miss, just a few miles away. How could that be connected to something in space millions of light years away?

II. Exploration

Review what you already know about the Electromagnetic Spectrum. (Answers to questions/choices are shown in **bold** print.) All forms of radiant energy travel through space in waves. Shorter wavelengths have (**more**, less) ___? energy, longer wavelengths have (more, **less**)____? energy, but they all travel at the (**same**, different) ____? speed. (Hint: What is the "speed of light"? **300,000km/sec.)**

1. What do we call the shortest waves of the EM spectrum?_____ **gamma rays**. What is an approximate wavelength for those waves? _____**10^{-15} meters** What do we call the longest waves of the spectrum and approximately how long are they?______ **radio waves, 10^{4} meters**
2. Put on your safety glasses now. We will use the Slinky toy to represent these waves of energy. One complete loop of the Slinky will represent one wavelength. Lay the meter stick flat on the table. Tape one end of the Slinky very securely to the zero end

of the meter stick and stretch it until you can hold the other end of the Slinky at the opposite end of the stick. (Remind students not to release the Slinky from the stretched position. Sudden compression often leads to a tangled Slinky and painfully pinched fingers!) Wavelength is measured from a point on the wave to a corresponding point on the next wave. Measure the wavelength at three different places along the stick. What is the wavelength? Location a.______________, location b.______________, location c.________

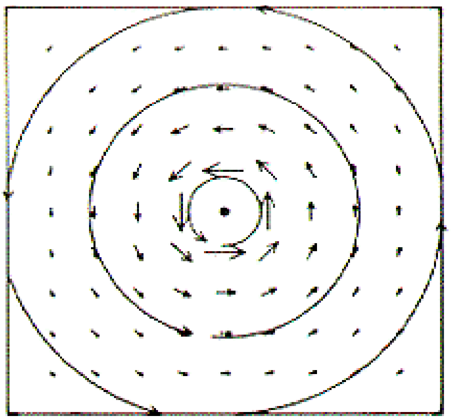
3. At this time neither end of the Slinky is in motion. Hold the zero end (observer) of the Slinky in place, but begin to slowly move the opposite end away from the observer. What happens to the wavelength?_______ **wavelength gets longer** Now begin moving in the opposite direction toward the observer. What is happening to the wavelength?_______ **wavelength becomes shorter** (Teacher can reinforce the result by holding the dangling Slinky in a vertical position and allowing it to gently oscillate up and down, with longer wavelengths going down away from your hand and shorter wavelengths as it returns toward your hand. Do not allow students to do this or tangled toys may result!)
4. What do we call this change in wavelength as a radiant object moves toward or away from the observer? ________ **Doppler Shift (Red or Blue Shift is also correct)**

   The same phenomenon occurs regardless of the region of the Electromagnetic spectrum we examine, and we can use this observation to tell us a great deal about the motion of objects very nearby or very, very far away.
5. The following USA Today article discusses how RADAR wave reflections from rain drops can be used to find out if parts of a storm cloud are moving toward or away from the RADAR station: http://www.usatoday.com/weather/wdoppler.htm
6. Use the colored pencils to fill in the pixels of the velocity RADAR image. RADAR (actually microwaves) are not in the visible light portion of the spectrum, but we will use Green and Red pixels to represent waves reflecting from parts of clouds coming toward or going away from the RADAR station. If they were visible, which would be longer waves, blue or red?_______**Red is a longer wavelength than Green** Therefore we will use (red, **green**) to represent wave reflections coming toward the station and (**red**, green) to represent wave reflections going away from the station. If the RADAR image shows an area where Green and Red pixels are side by side, coming toward and going away, at a speed of at least 45 knots in both directions, we know that this could indicate the rotation which accompanies a beginning tornado.
7. A TVS, Tornado Vortex Signature, alert is sent to everyone in the general area so that they can take precautions. Which area/areas of your image show something that could be a TVS? **3 TVS signatures are indicated**

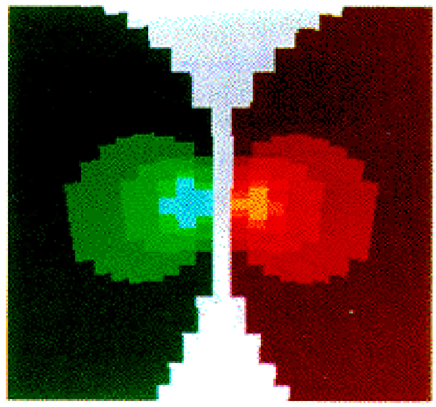
   Visit http://www.hprcc.unl.edu/nebraska/Greensburg3_small.gif to see another TVS image of a tornado that occurred in Greensburg, Nebraska.

The Doppler velocity RADAR image shows several towns in Montgomery County

Views of the model of a rotating cloud system. The image on the left (a) shows a top-down view of the rotation, as if we are looking from the top of the atmosphere. The image on the right (b) shows a cut-through of the cloud system, as if we are looking through the atmosphere.



(a)



(b)

Illinois on the night of June 2, 1999. The towns of Waggoner, Harvel, and Raymond are marked on the map. Three tornados touched down near the three towns at almost the same time! Pixels on the map are shown larger than actual.

8. Now use your colored pencils to complete the galaxy map of NGC 4254. This map shows the shift in wavelengths of visible light coming from the galaxy. Red shift indicates wavelengths getting longer or shorter? _____ **longer**. Blue shift would indicate wavelengths getting ______? **shorter** What does that suggest about the motion of the galaxy? **It seems to be rotating around a central point.** Visit the following web page to see maps of NGC 4254 and some other galaxies:

   http://www.obspm.fr/actual/nouvelle/jan06/virgo.en.shtml

   For a photograph of the galaxy visit the following webpage:

   http://www.astr.ua.edu/gifimages/ngc4254.html

A couple notes about the two images:

- The orientation for the two images is somewhat different. The RADAR map is oriented so that we are looking down at the surface of the Earth, as shown in picture (a) in the figure box above. The galaxy velocity map, however, is shown from the edge of the galaxy, similar to picture (b) in the figure box above.
- The velocity scales for the two images are also different – the RADAR image shows three velocity increments away from the RADAR station, with only one toward the station. The galaxy map shows two velocity increments away from the Earth and one toward. This is why the colors on the maps are slightly different.

However, the important point is that one object showing adjacent velocity measurements that are toward and away from the viewer indicate rotation.

III. Explanation

Meteorologists use Doppler Shift to locate potential tornados. Other scientists, using the same principal of a shift in wavelength from objects moving toward or away from the observer, can also use other regions of the Electromagnetic spectrum to observe possible motion.

How could an astronomer use the visible light waves coming from the sun to find out if the sun rotates on its axis? (Hint: refer to the image of the TVS and galaxy map above) **Blue shifted wavelengths on one limb of the sun coming toward us and red shifted wavelengths on the opposite limb rotating away from us**

If all of the visible light wavelengths coming from a very distant star appeared similar to our own nearby sun EXCEPT that all of the wavelengths seemed just a little longer than they "should" be, what might that suggest about the motion of the distant star? **It is moving away from the observer**

When you look at the galaxy map of NGC4254 and the other galaxies shown at the website, what do the colors tell you about the motion of the galaxies? **All of the galaxies indicate they are rotating**

IV. Evaluation

Write a short paragraph to respond to your teacher's question about how studying nearby tornadoes with RADAR is related to studying distant galaxies in space.

Velocity RADAR image

0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	4	0	0	0	0	0	0
3	3	2	2	4	2	0	0	0	0	0
3	3	4	4	3	2	0	0	0	0	0
3	3	3	3	3	3	3	3	3	0	0
3	Waggoner	3	3	3	3	3	3	3	0	0
3	3	3	3	4	2	1	2	3	3	0
3	1	2	2	2	Harvel	2	4	3	3	0
3	2	2	4	3	3	3	3	3	3	3
3	3	3	4	3	3	3	3	3	3	3
3	3	3	3	3	4	4	3	3	2	1
1	3	3	3	4	3	3	3	4	Raymond	2
1	4	4	4	4	0	0	0	0	0	4
1	4	0	4	3	0	0	0	0	0	0
Doppler RADAR		1in = 1 mile				Montgomery County Illinois				
0 blank (no cloud motion)		1 red (30 knots away)		2 yellow (20 knots away)		3 orange (5 knots away)		4 blue (20 knots toward)		

Velocity map of Galaxy NGC 4254

0	0	1	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0
1	1	1	1	1	2	3	0	0	4	0
0	1	1	1	1	2	3	3	0	4	4
1	1	1	1	1	2	3	3	4	4	4
0	1	1	1	2	2	3	3	4	4	4
1	1	1	1	2	3	3	4	4	4	4
1	1	1	2	2	3	4	4	4	4	4
1	1	1	2	2	3	4	4	4	4	4
0	0	1	2	0	3	3	4	4	4	0
0	0	0	0	0	3	4	4	4	4	4
0	0	0	0	0	4	4	0	4	4	0
0	0	0	0	0	4	0	0	0	4	0
0	0	0	0	0	0	0	0	0	0	0
			90000 light-years across, each pixel is 7500 light-years across							

0 blank (no stars from the galaxy)	1 red (approx. 100 km/s away)	2 orange (approx. 50 km/s away)	3 green (approx. 50 km/s toward)	4 blue (approx. 100 km/s toward)	